

DECLARATION

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do hereby solemnly and sincerely declare:

- 1) THAT I am well acquainted with the Japanese language  
and English language, and
- 2) THAT the attached is a full, true, accurate and  
faithful translation into the English language made  
by me of Japanese Patent Application No. 2002-364531.

The undersigned declares further that all  
statements made herein of his own knowledge are true and  
that all statements made on information and belief are  
believed to be true; and further that these statements  
were made with the knowledge that willful false statements  
and the like so made are punishable by fine or imprisonment,  
or both, under section 1001, of Title 18 of the United  
States Code and that such willful false statements may  
jeopardize the validity of the application or any patent  
issuing thereon.

Signed this 1<sup>st</sup> day of August, 2008.



A handwritten signature in black ink, appearing to read "Yukihiro Ikeda", is enclosed within a large, roughly drawn oval. The signature is fluid and cursive, with the name being the most legible part.

[Title of Document] Description

[Title of the Invention] ELECTRODE CATALYST FOR OXYGEN  
REDUCTION

[Scope of Claim for a Patent]

5 [Claim 1]

An electrode catalyst comprising a mixture composed of a particulate noble metal and at least one particulate rare-earth oxide, the mixture being supported on a conductive carrier, characterized in that 10 the particulate rare-earth oxide has an alkaline-earth metal as solid solution therein.

[Claim 2]

The electrode catalyst according to claim 1, characterized in that the conductive carrier is a 15 particulate carbon.

[Claim 3]

The electrode catalyst according to claim 1 or 2, characterized in that the noble metal is silver, platinum, or palladium.

20 [Claim 4]

The electrode catalyst according to any of claims 1 to 3, characterized in that the rare-earth oxide is cerium oxide.

[Claim 5]

25 The electrode catalyst according to any of claims 1 to 4, characterized in that alkaline-earth

metal is at least one of magnesium, calcium, and strontium.

[Claim 6]

The electrode catalyst according to claim 5,  
5 characterized in that the molar ratio of the cerium oxide to the alkaline-earth metal is from 1 : 0.005 to 1 : 0.3.

[Claim 7]

A gas diffusion electrode for brine  
10 electrolysis, characterized by use of the electrode catalyst according to any of claims 1 to 6.

[Detailed Description of the Invention]

[0001]

[Technical Field Pertinent to the Invention]

15 The present invention relates to an electrode catalyst, particularly an electrode catalyst suitable for a gas diffusion electrode, and to a process for preparing the electrode catalyst. More specifically, the invention relates to an electrode catalyst suitable  
20 for a gas diffusion electrode for oxygen reduction, applied to an oxygen cathode for brine electrolysis, a metal-air battery, or the like.

[0002]

[Prior Art]

25 A gas diffusion electrode allows a gas such as hydrogen, oxygen, or air to be supplied to a porous electrode and to react on the electrode. The gas

electrode is used in a fuel cell, a metal-air battery or the like which converts the chemical energy of gas to electric energy.

- In the field of brine electrolysis, a gas diffusion electrode in the form of a cathode, in which a cathodic reaction that can change from a current hydrogen generation reaction to an oxygen reduction reaction will produce a significantly reduced electrolysis voltage and which is capable of realizing energy-saving, is being developed.

Various gas diffusion electrodes are known for specific applications. The gas diffusion electrode using an electrolyte solution in the form of an aqueous solution is a laminated structure between gas diffusion and reaction layers, in the inner part of which a collector for electrical connection is embedded. Oxygen is supplied from the side of the gas diffusion layer, and the reaction layer is in contact with the electrolyte. After permeating the gas diffusion layer for diffusion in the inside, oxygen is subjected to a reduction reaction on an oxygen reduction catalyst fixed in the reaction layer.

[0003]

Previously known catalysts which are high in the activity to reduce oxygen include platinum, silver, organometallic complexes, and perovskite oxides, as described, for example, in Patent Documents 1 to 3 and Non-Patent Document 1. These catalysts mainly use a

particulate carbon as a carrier, and are used as supported on it in a highly dispersed condition.

However, their catalytic activities are not sufficient, and use of them as a cathode leads to 5 elevated overvoltages. As a result, the oxygen cathode system cannot be economically advantageous over the current hydrogen cathode system, in view of the costs including the oxygen cost. Thus, there is a need for a catalyst with higher oxygen reduction activity.

10 [0004]

[Patent Document 1] JP-A-2000-212788

[Non-Patent Document 1] F.C. Anson, et al., J. Am. Chem. Soc., 1980, 102, 6027

[Patent Document 2] JP-A-02-257577

15 [Patent Document 3] JP-A-07-289903

[0005]

[Problems To Be Solved By The Invention]

An object of the present invention  
contemplates the provision of an electrode catalyst with  
20 higher oxygen reduction activity which is obtained by  
allowing, in a composite catalyst of a particulate noble  
metal and a particulate rare-earth oxide, alkaline-earth  
metal to form a solid solution in the particulate rare-  
earth oxide.

25 [0006]

[Measure For Solving The Problem]

As the result of earnest and repeated research  
on the above described problems, the present inventors

have found that an electrode catalyst comprising a mixture composed of a particulate noble metal and at least one particulate rare-earth oxide supported exhibits enhanced oxygen reduction activity when an  
5 alkaline-earth metal is allowed to form a solid solution in the above described particulate rare-earth oxide.

Thereby, the present invention is accomplished.

[0007]

Thus, the present invention is as follows:

10 (1) An electrode catalyst comprising a mixture composed of a particulate noble metal and at least one particulate rare-earth oxide, the mixture being supported on a conductive carrier, characterized in that the particulate rare-earth oxide has an alkaline-earth  
15 metal as solid solution therein.

(2) The electrode catalyst according to item (1), characterized in that the conductive carrier is a particulate carbon.

20 (3) The electrode catalyst according to item (1) or (2), characterized in that the noble metal is silver, platinum, or palladium.

(4) The electrode catalyst according to items (1) to (3), characterized in that the rare-earth oxide is cerium oxide.

25 (5) The electrode catalyst according to items (1) to (4), characterized in that alkaline-earth metal is at least one of magnesium, calcium, and strontium.

(6) The electrode catalyst according to item

(5), characterized in that the molar ratio of the cerium oxide to the alkaline-earth metal is from 1 : 0.005 to 1 : 0.3.

(7) A gas diffusion electrode for brine electrolysis, characterized by use of the electrode catalyst described in any of the items (1) to (6).

[0008]

The present invention is described below in detail.

10       The electrode catalyst of the present invention is an electrode catalyst comprising a mixture composed of a particulate noble metal and at least one particulate rare-earth oxide, the mixture being supported on a conductive carrier, characterized in that  
15      the particulate rare-earth oxide has an alkaline-earth metal as solid solution therein. In the invention, high oxygen reduction activity can be obtained by forming the solid solution of the alkaline-earth metal in the rare-earth oxide. More specifically, according to the  
20      electrode catalyst of the invention, the interface between the particulate noble metal and the rare-earth metal oxide particle provides a reaction active site, and produces enhanced activity due to improved oxygen ion and electrical conductivities by forming the solid  
25      solution formation of the alkaline-earth metal in the rare-earth metal oxide.

[0009]

According to the invention, as long as it is

fixed to the carrier, a smaller noble metal particle, which is the main catalyst, is preferred because the total surface area of the noble metal as the main catalyst is increased. Particularly, the particle 5 diameter is preferably 200 nm or less, more preferably 100 nm or less. If the particle diameter is too large, i.e. more than 200 nm, the surface area of the noble metal, which is the main catalyst, is decreased, the satisfactory oxygen reduction activity being unable to 10 be achieved. Also, when the size of the rare-earth oxide fixed to the carrier decreases, the number of the active sites is increased. Particularly, the particle diameter is preferably 500 nm or less. If the particle diameter is too large, i.e. more than 500 nm, the 15 interface serving as the active site is less easily formed, and the satisfactory oxygen reduction activity is not achieved.

[0010]

Noble metals used for the invention include 20 gold (Au), silver (Ag), ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), platinum (Pt), or the like, and are preferably silver (Ag), platinum (Pt), and palladium (Pd).

For the purpose of increasing the surface area 25 of catalyst, the electrode catalyst of the invention is usually supported on a conductive carrier which is large in the surface area.

Typically, a fine particulate carbon is used

as the conductive carrier. For example, an activated carbon, and a carbon black with a BET specific surface area of 30 to 2,000 m<sup>2</sup>/g may be cited. The so-called furnace black, lamp black, acetylene black, channel  
5 black, thermal black, or the like may be used.

Preferably, the carbon particle has a diameter of 0.01 μm to 1 μm.

[0011]

Rare-earth oxides used for the invention  
10 include oxides of scandium (Sc), yttrium (Y), lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb),  
15 lutetium (Lu), or the like, and are preferably cerium oxide, holmium oxide, and gadolinium oxide.

Alkaline-earth metals used for the invention include beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), or the like.

20 [0012]

When the amounts of presence of a particulate noble metal and at least one particulate rare-earth oxide are set to A and B, respectively, the compositional ratio between the particulate noble metal  
25 and the particle of at least one kind of rare-earth oxide contained in the electrode catalyst of the invention is preferably 0.01 to 4.0 in a molar ratio of B to A (B/A). A molar ratio of less than 0.01 will

result in an insufficient amount of the particulate rare-earth oxide, and thus will lead to poor formation of the interface providing the active site. Conversely, a molar ratio of more than 4.0 will result in an excessive amount of rare-earth oxide, producing a structure in which the rare-earth oxide covers up the particulate noble metal, and again will lead to a reduced interface. In both instances, oxygen reduction activity cannot be enhanced.

10 [0013]

The particulate rare-earth oxide having an alkaline-earth metal as solid solution therein, contained in the electrode catalyst of the invention, preferably has a rare-earth oxide to alkaline-earth metal molar ratio of 1 : 0.005 to 1 : 0.3. An alkaline-earth metal molar ratio of less than 0.005 is unfavorable because of no enhancement in oxygen ion and electrical conductivities. An alkaline-earth metal molar ratio of more than 0.3 is also unfavorable because the alkaline-earth metal cannot form solid solution.

The proportion of the electrode catalyst substance is preferably 10 to 90% by weight, based on the weight of the particulate carbon. An insufficient amount of the electrode catalyst substance will result in the reduced total reaction surface area of the substance, and thus will not produce sufficient oxygen reduction activity. Alternatively, an excessive amount of the electrode catalyst substance will result in the

substance becoming prone to flocculate, lead to reducing the total reaction surface area of the substance, and thus not producing sufficient oxygen reduction activity.

[0014]

5       The process for preparing the electrode catalyst of the invention is described below.

(1) A method for supporting noble metal

Various preparation methods may be used to support noble metal on a conductive carrier; the  
10 following preparation method is generally used.

A particulate carbon powder is generally used as a conductive carrier. The case of employing the powder as the carrier is described below.

First, in a dispersion step, the particulate  
15 carbon powder is dispersed in a solution of noble metal salt. The noble metal salt may be any soluble noble metal salt, including the nitrate, chloride, sulfate, carbonate, or acetate of a noble metal.

[0015]

20       The solvent used is generally water.

Optionally, a small amount of alcohol, organic solvent, acid, alkali, or the like may be also employed. Any solvent in which noble metal salt can be dissolved may be used.

25       In order to disperse the particulate carbon powder in this solution, various methods may be used, including agitation using a stirrer or a stirring rod, use of a kneader, ultrasonic dispersion, use of a

homogenizer, use of an ultrasonic homogenizer, or the like. The method involving agitation using a stirrer is typically employed because of its ease at use.

In a reduction step, the noble metal ion is  
5 reduced using a reducing agent to support the noble metal on the particulate carbon powder. The reducing agent used may be hydrazine, formalin, or the like. The reduction treatment is followed by filtration, washing and drying to provide a noble metal-loaded carbon  
10 powder.

[0016]

Alternatively, the following additional preparation method may be also used.

In a dispersion step, the particulate carbon  
15 powder is dispersed in a solution of noble metal salt. The noble metal salt may be any soluble noble metal salt, including the nitrate, chloride, sulfate, carbonate, or acetate of a noble metal. The nitrate is preferred because it is almost free from the remaining  
20 of chlorine, sulfur, or the like after thermal decomposition.

The solvent used is generally water. Optionally, a small amount of alcohol, organic solvent, acid, alkali, or the like may be also employed. Any  
25 solvent in which noble metal salt can be dissolved may be used.

[0017]

In order to disperse the particulate carbon

powder in this solution, various methods may be used, including agitation using a stirrer or a stirring rod, use of a kneader, ultrasonic dispersion, use of a homogenizer, use of an ultrasonic homogenizer, or the like. The method involving agitation using a stirrer is typically employed because of its ease at use.

In a drying step, the suspension is then evaporated to dryness. The drying method may be any method by which the solvent can be removed, including retention in a dryer or an oven at 100°C for 12 hours, use of a vacuum dryer or an evaporator, or the like.

[0018]

In a firing step, a catalyst precursor, which is the dispersion of the nitrate and the particulate carbon obtained in the drying step, is subjected to thermal decomposition reaction to provide a noble metal-loaded carbon powder having the highly dispersed particulate noble metal. In order to avoid progression of oxidation of the particulate carbon on the conductive carrier, heating is preferably carried out in a non-oxidative atmosphere of nitrogen or the like. However, if the particulate noble metal can be formed at such a low temperature that the particulate carbon is not oxidized, heating can be performed even in air or an atmosphere containing oxygen. The temperature used during firing, at which the noble metal is formed by thermal decomposition, is preferably as low as possible. The preferred firing temperature is 200 to 700°C. If

firing is performed at too high temperature, then the particulate noble metals will flocculate, resulting in a larger diameter of the noble metal. Alternatively, if firing is carried out at too low temperature, then the 5 thermal decomposition of noble metal salt will not completely occur, thus, producing no particulate noble metal. Firing/thermal decomposition time is preferably 1 to 10 hours.

[0019]

10 (2) A method for supporting a particle of rare-earth oxide having an alkaline-earth metal as solid solution therein

A method for supporting rare-earth oxide having an alkaline-earth metal as solid solution therein 15 is then described.

In a dispersion step, a carbon powder is dispersed in a solution containing rare-earth salt and alkaline-earth metal salt. The rare-earth salt is preferably a nitrate because the nitrate is subjected to 20 firing in an atmosphere of an inert gas in a firing step to provide rare-earth oxide. Preferably, the alkaline-earth metal salt is also a nitrate because a chloride, a sulfate, or the like produces remaining chlorine, sulfur or the like, respectively, after firing.

25 [0020]

In order to disperse the silver-loaded carbon powder in this solution, various methods may be used, including agitation using a stirrer or a stirring rod,

use of a kneader, ultrasonic dispersion, use of a homogenizer, use of an ultrasonic homogenizer, or the like. The method involving agitation using a stirrer is typically employed because of its ease at use.

5        This solution may be directly dried in a subsequent drying step. However, an alkali such as sodium hydroxide or ammonia may also be added to form a hydroxide, followed by evaporation to dryness.

In a drying step, the suspension is then  
10 evaporated to dryness. The drying method may be any method by which the solvent can be removed, including retention in a dryer or an oven at 100°C for 12 hours, use of a vacuum dryer or an evaporator, or the like.

[0021]

15        In a firing step, the electrode substance obtained in the drying step is subjected to thermal decomposition reaction to support, on the carbon, the rare-earth oxide having the alkaline-earth metal as solid solution therein. In order to avoid progression  
20 of oxidation of the particulate carbon on the conductive carrier, heating is preferably carried out in a non-oxidative atmosphere of nitrogen or the like. However, if a particle of the rare-earth oxide having the alkaline-earth metal as solid solution therein can be  
25 formed at such a low temperature that the particulate carbon is not oxidized, heating can be performed even in air or an atmosphere containing oxygen. The firing temperature, at which the rare-earth oxide having the

alkaline-earth metal as solid solution therein is formed by thermal decomposition, is preferably as low as possible. The preferred firing temperature is 200 to 1000°C. In addition, retention time is preferably 1 to 5 10 hours. If firing is performed at too high a temperature, then the particles of rare-earth oxide having divalent metal allowed to form solid solution therein will flocculate, resulting in a larger diameter of the particle. Alternatively, firing at too low a 10 temperature is unfavorable because the thermal decomposition of rare-earth nitrate will not completely occur to produce the residue thereof, or because alkaline-earth metal will not form solid solution in rare-earth oxide.

15 After the heat treatment, the powder produced is optionally pulverized. Thereafter, the powder pulverized may be used for preparing a gas diffusion electrode, or for supporting a metal or an oxide thereof. The pulverization may be carried out by a 20 variety of methods using a mortar, various mills, or the like.

[0022]

In a method for preparing the electrode catalyst of the invention, (1) a silver particle is 25 supported on a particulate carbon powder, and (2) a particle of rare-earth oxide having alkaline-earth metal that is allowed to form solid solution therein is supported on the powder. However, the steps may be

performed in any order: the silver particle may be formed on the particulate carbon, followed by supporting the particle of rare-earth oxide having an alkaline-earth metal as solid solution therein, or the particle 5 of rare-earth oxide having alkaline-earth metal that is allowed to form a solid solution therein may be formed on the particulate carbon, followed by supporting the silver particle. Further, the silver particle and the particle of rare-earth oxide having an alkaline-earth 10 metal that is allowed to form a solid solution therein may be supported simultaneously on the particulate carbon, using a mixed solution of silver salt, rare-earth salt, and alkaline-earth metal salt. In addition, many kinds of rare-earth oxides and silver may be 15 supported.

In addition to the above methods, the supporting on the conductive carrier may be carried out using a colloidal solution of silver or rare-earth oxide, or a suspension having powder dispersed in a 20 solvent.

Of the electrode catalyst obtained through these steps, the crystal structure may be determined using powder X-ray diffractometry.

[0023]

25 The electrode catalyst obtained by these methods was evaluated using a channel flow electrode method. The measuring cell shown in FIG. 1 was employed for the measurement based on the channel flow electrode

method. The measuring cell indicated in FIG. 1 has a structure in which an oxygen-saturated electrolyte is introduced at an electrolyte inlet 3, passed through an electrolyte passage 4 with a thickness of 0.05 mm, and  
5 discharged at an electrolyte outlet 5. Under this situation, the flow of an electrolyte contacting a working electrode 1 is adequate if being in the form of a laminar flow. The acrylic resin plate has a cavity 2 × 5 mm in area, 2 mm in depth in a part thereof, and the  
10 cavity, filled with an electrode catalyst, is rendered the working electrode 1. The working electrode 1 has a working electrode wiring 2 for electric connection. A liquid-junction portion 6 with a reference electrode is also provided. The diffusion rate of dissolved oxygen  
15 in the electrolyte can be controlled by changing the flow rate of the electrolyte. The electrolyte is flowed at a fixed flow rate to allow oxygen reduction reaction to occur on the working electrode 1, and current-voltage characteristics (I-V characteristics) at the time are  
20 measured to evaluate oxygen reduction activity.

[0024]

[Mode of Carrying Out The Invention]

The present invention is described in further details, based on Examples and the like. However, the  
25 invention is not intended to be limited in any manner by Examples and the like.

[Example 1]

(Preparation of a silver-loaded carbon)

A carbon containing 50% by weight of silver was prepared as described below.

Two grams of carbon black (from Mitsubishi Chemical Corporation: Ketjen Black EC-600JD) are ground 5 using a mill (from Janke & Kunkel Co.: A10) and 3.15 g of silver nitrate (from Wako Pure Chemical Industries Ltd.) and then dispersed in 200 ml of an aqueous solution. This dispersion was stirred for 15 minutes using a stirrer, and then subjected to the evaporation 10 of the water content in an oven at 100°C, followed by drying to provide a powder. Subsequently, this powder was subjected to firing in a stream of nitrogen at 250°C for one hour, to thermally decompose silver nitrate, using an inert gas firing furnace (from Yamada Electric 15 MFG. Co., Ltd.: Model VMF165), and then this powder was ground using the mill to provide a carbon containing 50% by weight of silver.

[0025]

Next, 0.217 g of cerium nitrate ( $\text{Ce}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ , from Wako Pure Chemical Industries Ltd.) and 0.263 g of 0.1 M strontium nitrate prepared from strontium nitrate ( $\text{Sr}(\text{NO}_3)_3$ , from Wako Pure Chemical Industries Ltd.) were added to 0.108 g of the silver-loaded carbon powder to provide a silver to cerium to strontium molar 25 ratio of 1 : 1 : 0.05. This mixture was ultrasonically dispersed in water for 5 minutes.

Further, the water content was evaporated in an oven at 100°C, followed by drying to provide a sample

powder. This powder was subjected to firing in a stream of nitrogen at 400°C for one hour, using the inert gas firing furnace, and ground employing the mill to provide an electrode catalyst powder. The powder X-ray diffraction of the electrode catalyst powder was measured. Measurement was carried out using was RINT-2500 (from Rigaku Corporation) as the apparatus for the diffraction and copper  $K\alpha$  radiation ( $\lambda = 1.54184 \text{ \AA}$ ) as the radiation source. Identification of a peak provided the detection of Ag and  $\text{CeO}_2$ . A diffraction angle ( $2\theta$ ) corresponding to the main diffraction line of  $\text{CeO}_2$  (111) was  $28.585^\circ$ . The conversion of this to a grating constant provided  $5.409 \text{ \AA}$ . The grating constant of  $\text{CeO}_2$  alone is  $5.411 \text{ \AA}$ . The solid solution formation of strontium produced the decreased grating constant.

[0026]

A small amount of liquid paraffin (from Kishida Chemical Co., Ltd.) was added to the electrode catalyst powder thus prepared, followed by mixing in a mortar to produce a paste. This paste was packed in a working electrode portion, for evaluation using a channel flow electrode method. A platinum wire and a silver/silver chloride electrode were rendered a counter electrode and a reference electrode, respectively. Bubbling was carried out in a 0.1 M aqueous sodium hydroxide solution with pure oxygen for one hour to make this aqueous sodium hydroxide solution oxygen-saturated. In addition, the solution, the flow rate of which was

fixed at 83.2 cm/sec, was kept at -0.6 V for 10 minutes, and the working electrode was then swept at 10 mV/sec from the potential +0.1 V to -0.6 V to measure a potential-current curve. The results obtained are 5 depicted in FIG. 2. The evaluation results shows higher oxygen reduction activity.

[0027]

[Example 2]

Magnesium nitrate ( $\text{Mg}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$  (from Wako 10 Pure Chemical Industries Ltd.) was used instead of strontium nitrate in Example 1 so as to provide a silver to cerium to magnesium molar ratio of 1 : 1 : 0.05. However, preparation and evaluation were carried out otherwise as described in Example 1. The measurement of 15 the powder X-ray diffraction of the electrode catalyst powder prepared resulted in the detection of Ag and  $\text{CeO}_2$ . A diffraction angle ( $2\theta$ ) corresponding to the main diffraction line of  $\text{CeO}_2$  (111) was  $28.669^\circ$ . The conversion of this to a grating constant provided 5.393 20  $\text{\AA}$ . The grating constant of  $\text{CeO}_2$  alone is 5.411  $\text{\AA}$ . The solid solution formation of magnesium produced the decreased grating constant.

The measurement of a potential-current curve using a channel flow electrode is depicted in FIG. 2. 25 The evaluation results shows higher oxygen reduction activity.

[0028]

[Comparative Example 1]

As described in Example 1, a carbon containing 50% by weight of silver was prepared. Next, 0.217 g of cerium nitrate ( $\text{Ce}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ , from Wako Pure Chemical Industries Ltd.) was added to 0.108 g of the silver-loaded carbon powder to provide a silver to cerium molar ratio of 1 : 1. This mixture was ultrasonically dispersed in water for 5 minutes.

Further, the water content was evaporated in an oven at 100°C, followed by drying to provide a sample powder. This powder was subjected to firing in a stream of nitrogen at 400°C for one hour, using the inert gas firing furnace, and ground employing the mill to provide an electrode catalyst powder.

The measurement of the powder X-ray diffraction of the electrode catalyst powder prepared resulted in the detection of Ag and  $\text{CeO}_2$ . A diffraction angle ( $2\theta$ ) corresponding to the main diffraction line of  $\text{CeO}_2$  (111) was 28.464°. The conversion of this to a grating constant provided 5.411 Å.

The measurement of a potential-current curve using a channel flow electrode is depicted in FIG. 2. The evaluation results show that the oxygen reduction current increased from a further lower potential compared to those in Examples 1 and 2.

[0029]

[Effect of The Invention]

The electrode catalyst of the present invention exhibits high oxygen reduction activity as an

electrode catalyst for oxygen reduction by forming a solid solution of alkaline-earth metal in rare-earth oxide, in a composite catalyst of a silver particle and a particulate rare-earth oxide. Use of the electrode 5 catalyst of the invention for a gas diffusion electrode may reduce oxygen reduction overvoltage in the electrolysis of an alkali metal halide aqueous solution such as brine using an ion exchange membrane. As a result, it has become possible to reduce the electric 10 power used for electrolysis to manufacture products such as chlorine and caustic soda, thus resulting in a lower cost.

[Brief Description of the Drawings]-

[FIG. 1]

15 FIG. 1 is an illustrative picture of an evaluation device using a channel flow electrode method.

[FIG. 2]

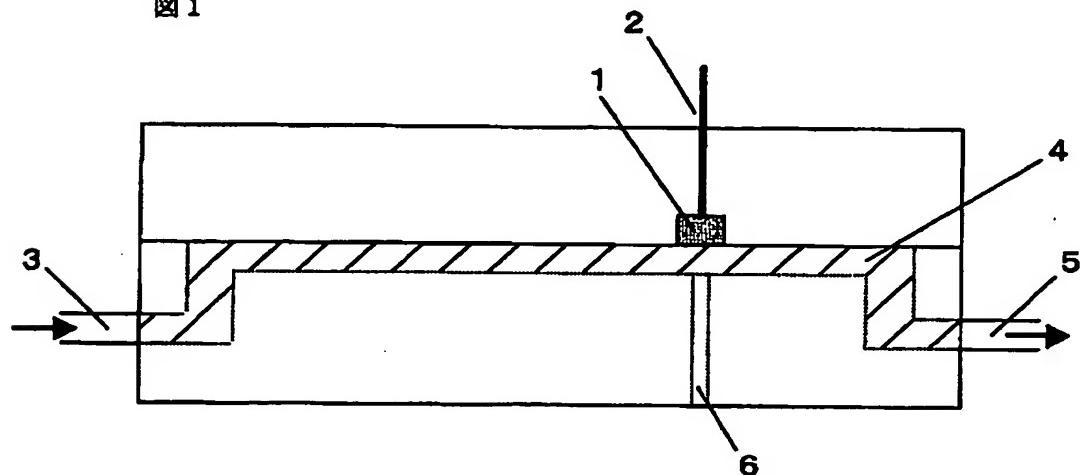
FIG. 2 is an illustration of the result of evaluating electrode catalysts in Examples and 20 Comparative Example, using a channel flow electrode method.

【書類名】 図面

【図1】

[Kind of Document] Drawings  
 [Fig. 1]

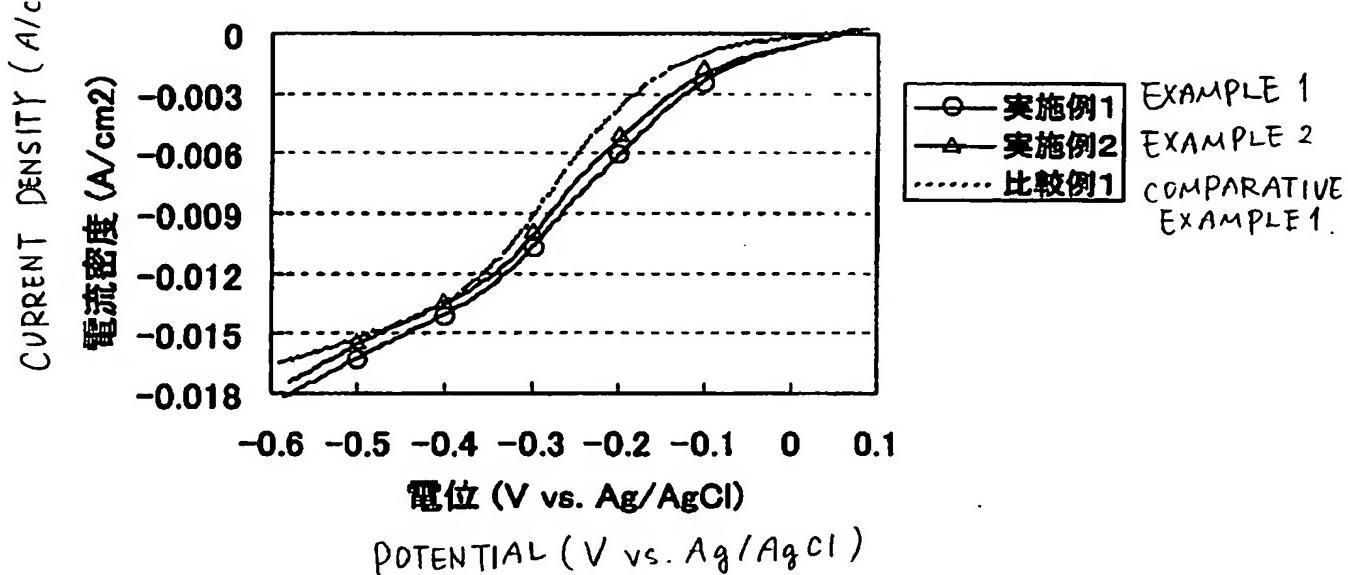
図1



【図2】

[Fig. 2]

図2



[Title of Document] Abstract

[Abstract]

[Problem]

To provide an electrode catalyst which is suitable as a oxygen reduction catalyst and has oxygen reduction activity higher than that of a conventional electrode catalyst.

[Solution]

An electrode catalyst with higher oxygen reduction activity is realized by allowing, in a composite catalyst of a particulate noble metal and a particulate rare-earth oxide, alkaline-earth metal to form a solid solution in the particulate rare-earth oxide.

[Selected Drawing] None